CDX-U
Recent Results

R. Majeski, R. Kaita, M. Boaz, P. Efthimion, T. Gray, D. Hoffman, B. Jones, H. Kugel, T. Munsat, C. Neumeyer, A. Post-Zwicker, S. Raftopoulos, V. Soukhanovskii, J. Spaleta, G. Taylor, J. Timberlake, R. Woolley, *PPPL*,
M. Finkenthal, D. Stutman, *Johns Hopkins University*,
G. Antar, R. Doerner, S. Luckhardt, R. P. Seraydarian, R. W. Conn *UCSD*,
R. Maingi, M. Menon, *ORNL*,
R. Causey, D. Buchenauer, M. Ulrickson *SNL*,
M. Maiorano, *Rutgers University*
D. Rodger, G. Lovercheck, *Drexel University*

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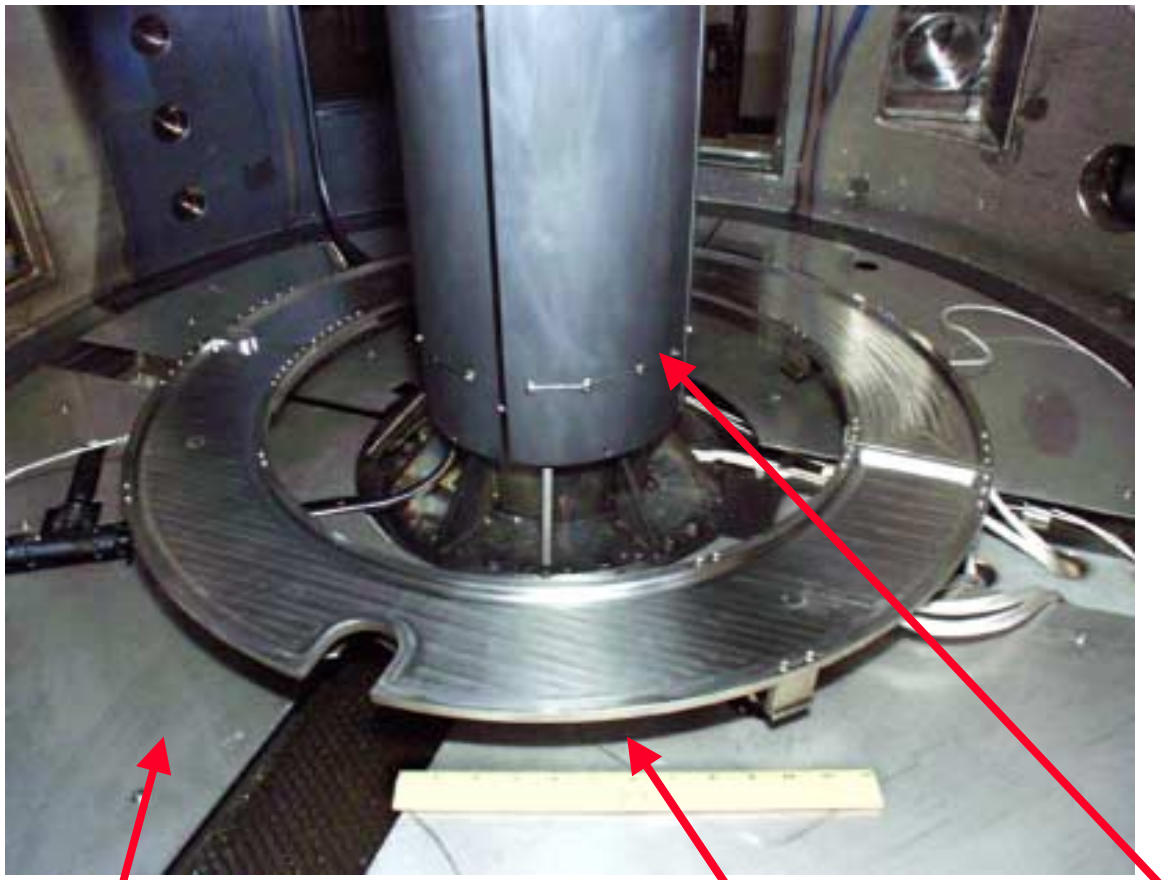
Operational Summary

- CDX-U has been operating with the toroidal tray for nearly a year
- Have had problems with uniformity of the lithium coverage of the tray, surface cleanliness
- But - initial results indicated:
  - Better plasma performance
  - Reduced plasma conditioning overhead
  - Reduced impurities
  - Very low recycling on liquid lithium
    - » Solid lithium is not as effective
- In December the entire chamber and virtually all of the viewports were coated with lithium.
  - Coating was very uniform (visually)
  - Cause of the accident still unknown

Operational Summary (cont'd)

- Coating incident disabled most of our gate valves
  - Wouldn't adequately seal
  - Couldn't replace or clean the windows
  - Spectroscopic diagnostics were limited to one view of the tray and one view of the centerstack
- However:
  - Base pressure dropped by 3×, to the mid 10^{-8} range
  - Plasma performance afterward was good
- Recently restored gate valve operation in most cases
  - Operated the valves for dozens of cycles
  - Most windows have now been cleaned, reinstalled
  - Resumed installation of diagnostics, additional gas puffing

CDX-U lithium tray limiter



• Discharges run on bare SS tray to establish baseline prior to lithium filling

• 34 cm major radius, 10 cm wide, 0.64 cm deep

• Fabricated in two halves with a toroidal electrical break
  -Isolated from vessel
  -Halves connected to electrical feedthroughs

• Heaters beneath for temperature control up to 400°C. Typ. ops 200 - 250°C

• Heat shield on center stack

• Heat/lithium shield between tray and lower vacuum flange

• Tray temperature monitored with thermocouples around edge

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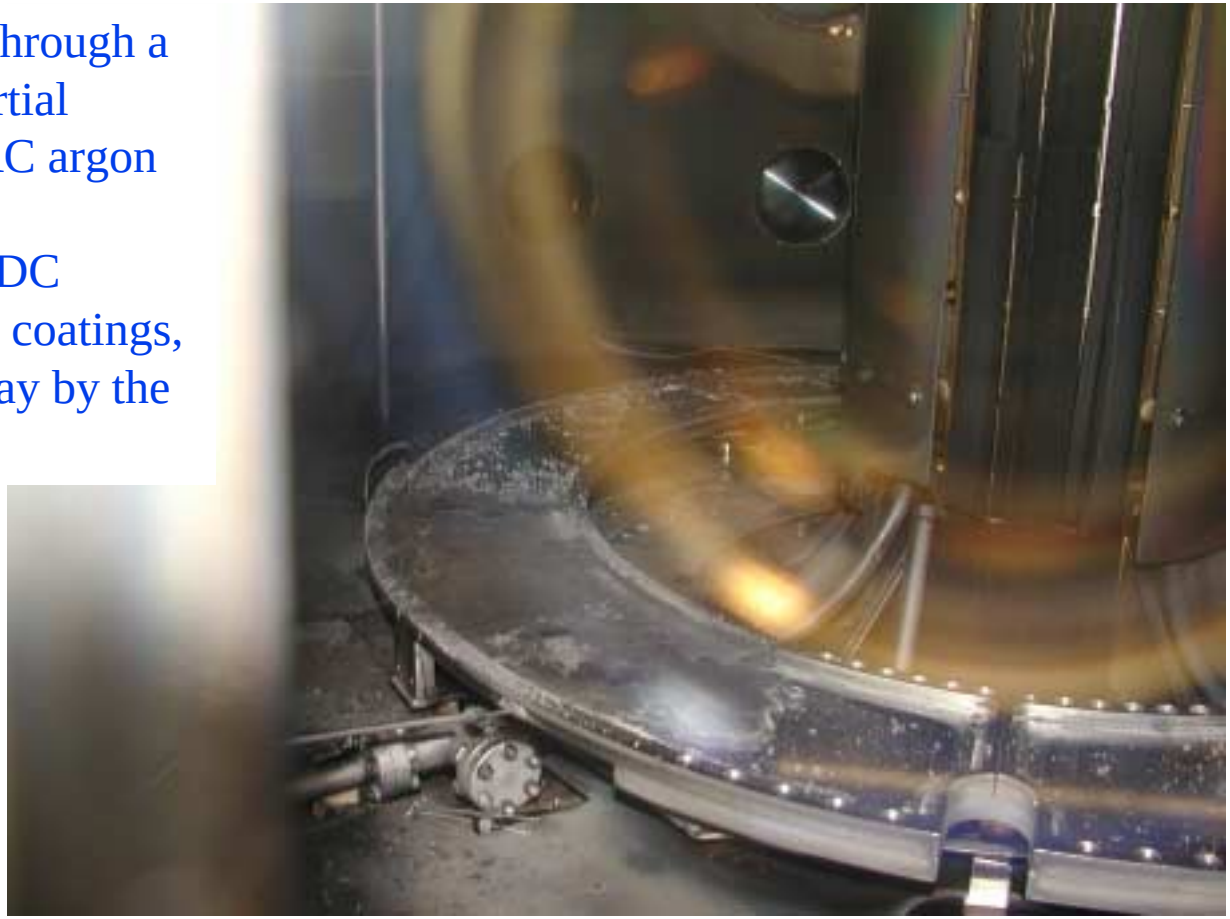
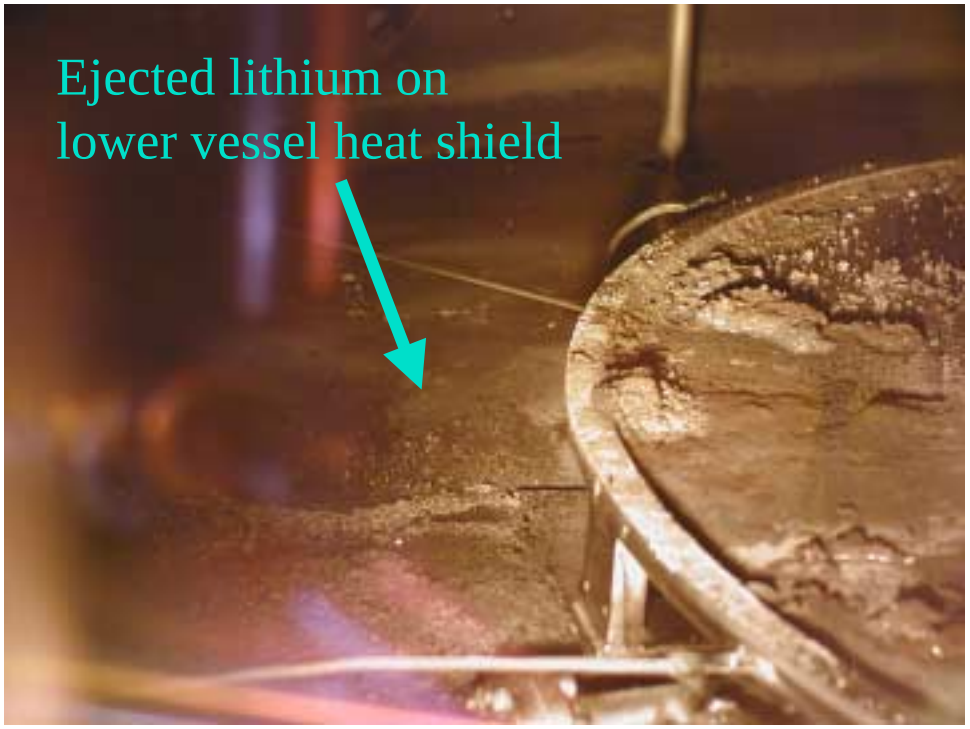
Lithium tray fill was nonuniform, partly oxidized

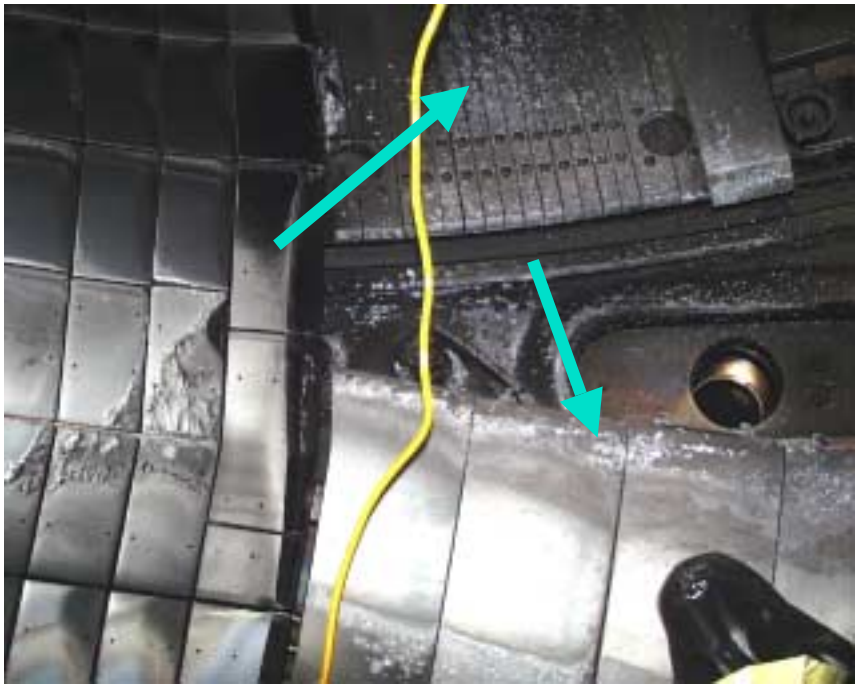
- Photograph of the tray through a vacuum window after partial cleaning of the tray via AC argon glow discharge cleaning.
- Many hours of argon GDC required to remove oxide coatings, promote wetting of the tray by the lithium



Arc activity introduced lithium "aerosol" into the edge plasma

- Lithium particulate ejected from tray. J x B motion produced a spray pattern of lithium outboard of tray.
- Depositions resemble those found around the DOLLOP crucible in TFTR





Note that rapidly varying CDX-U vacuum OH, PF fields produced *no visible motion* of the liquid lithium

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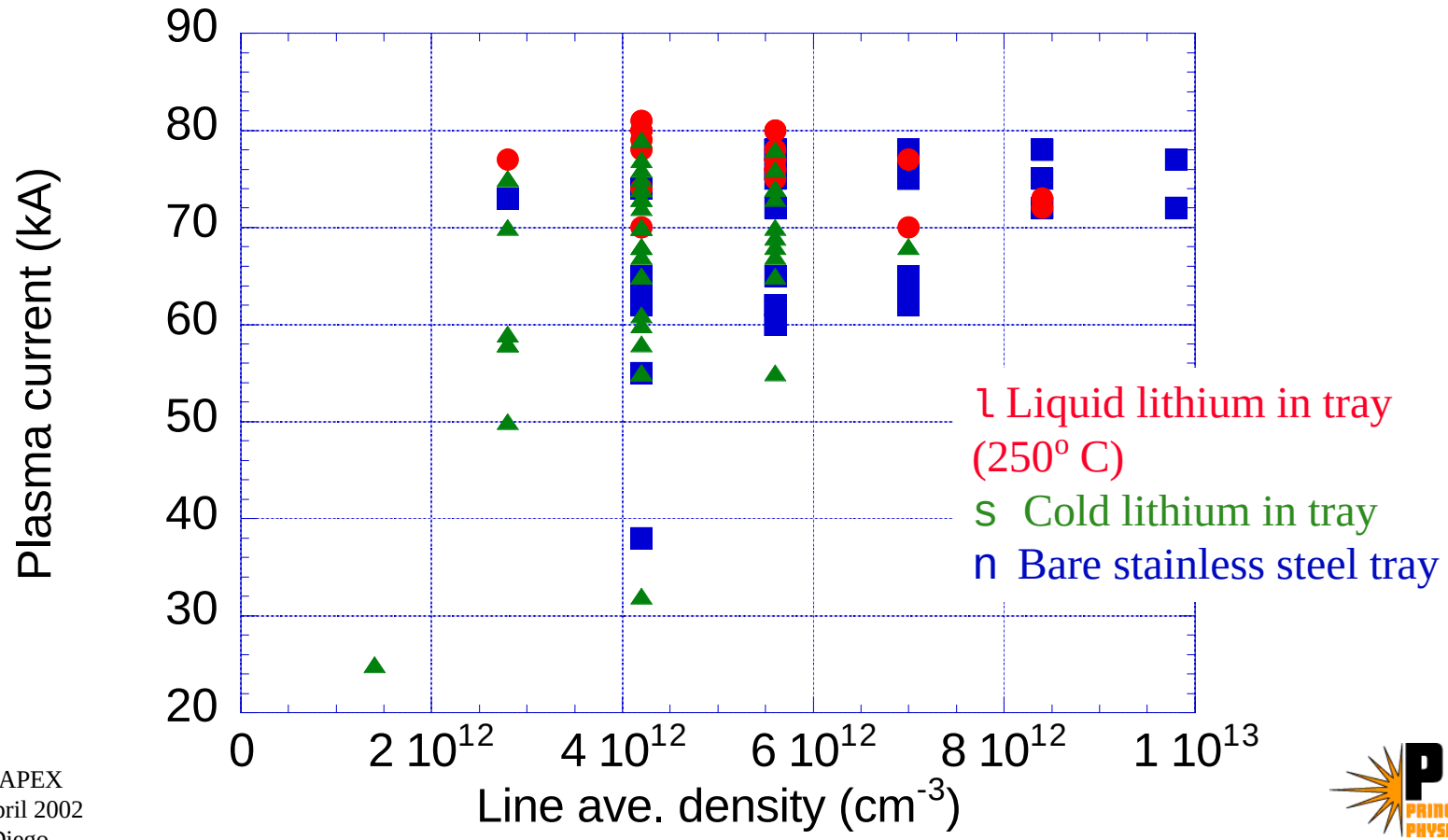
Discharge performance was improved with the toroidal liquid lithium limiter

- Highest current discharges were obtained with liquid lithium (T=250 ^{o}C) in tray
  - Better performance than with Ti gettering. Surface does not saturate.
  - Density was limited. More gas puffing ≠ more density with liquid lithium in the tray



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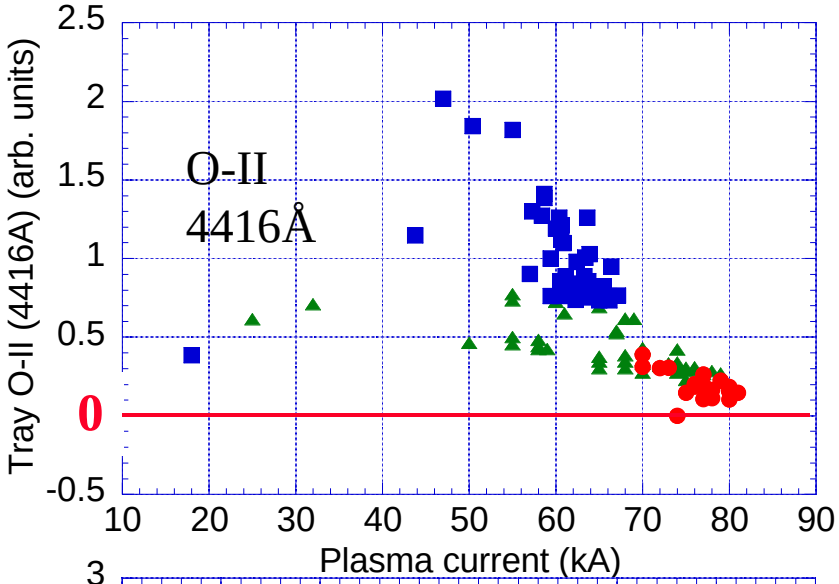
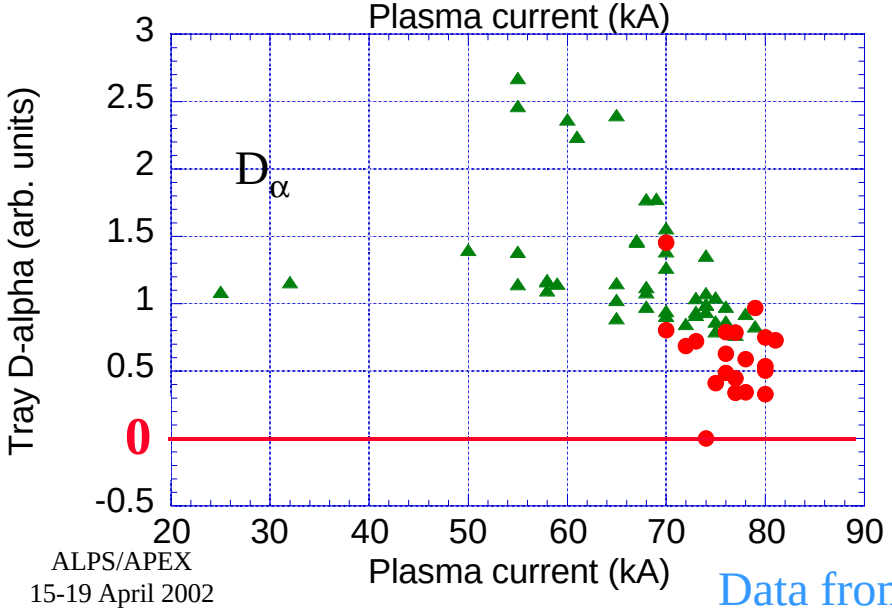
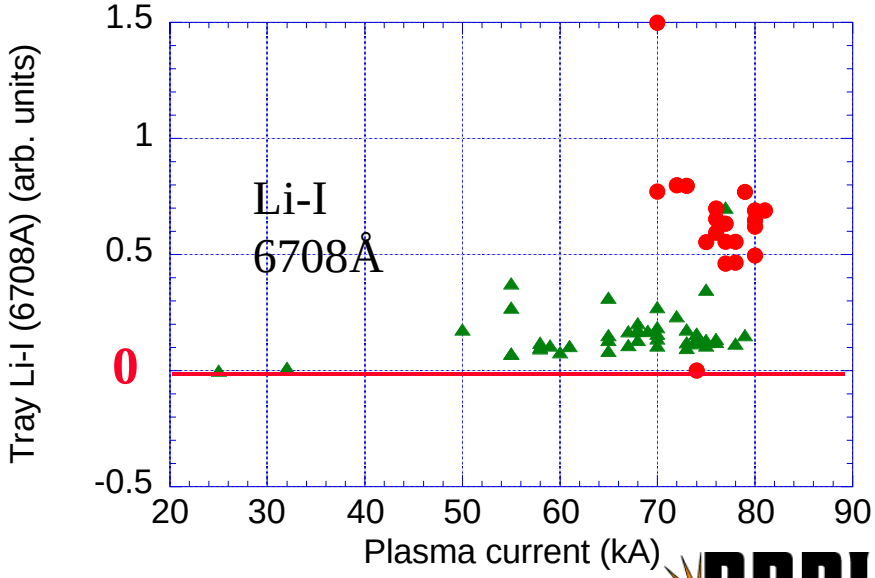
Highest plasma currents are correlated with lowest D_α, oxygen emission at the tray





- Least oxygen, D_α light for liquid lithium
- Most lithium light for liquid lithium

l Liquid lithium in tray (250 ° C)
s Cold lithium in tray
n Bare stainless steel tray



Data from the ORNL tray filterscope

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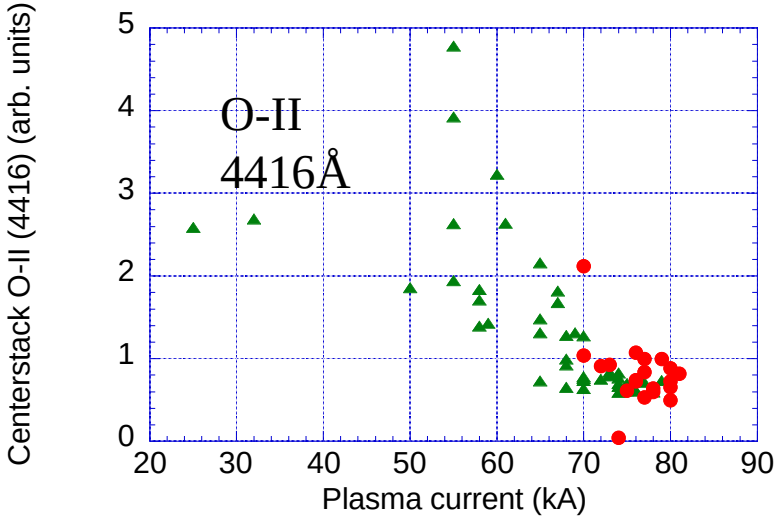
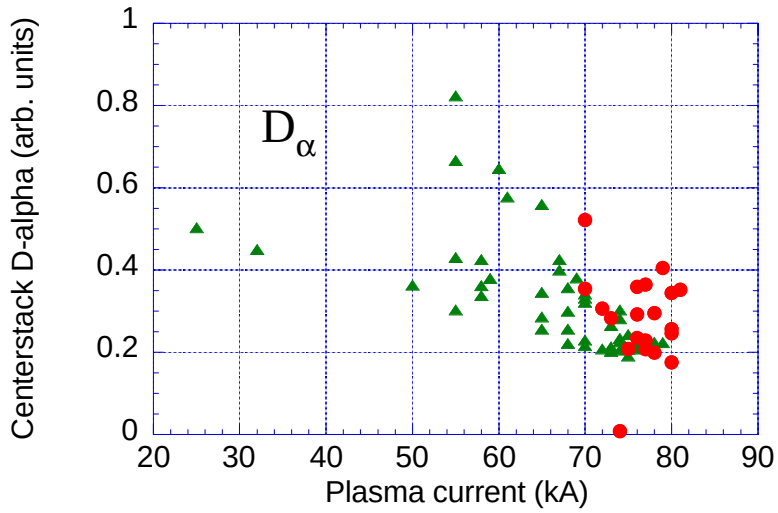
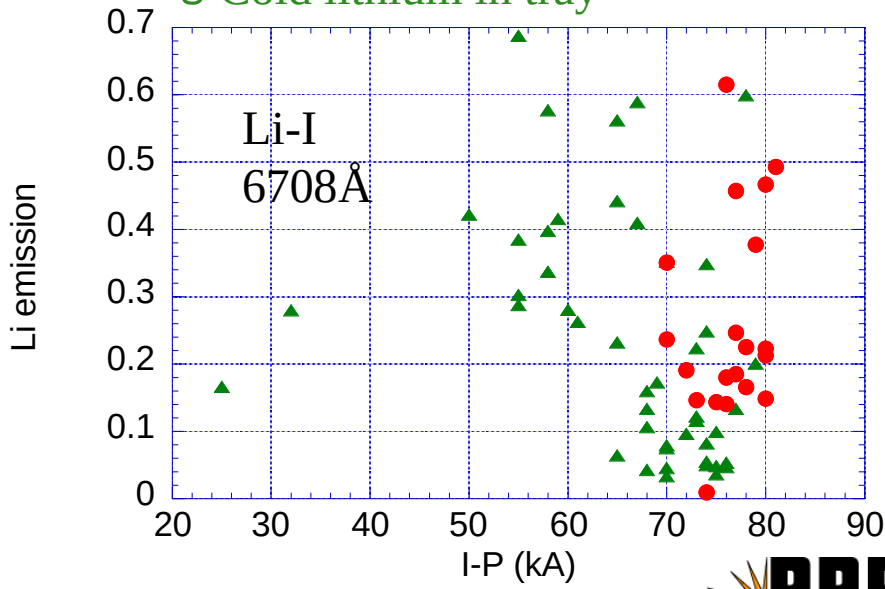
Performance enhancement is due to interaction with liquid lithium in the tray





- Highest performance also correlates with lowest D_α,O centerstack light. But:
  - Liquifying the lithium does not produce a further reduction in centerstack D_α, O
  - Lithium emissions do not increase with a hot tray

l Liquid lithium in tray (250 ° C)
s Cold lithium in tray



Data from the ORNL centerstack filterscope

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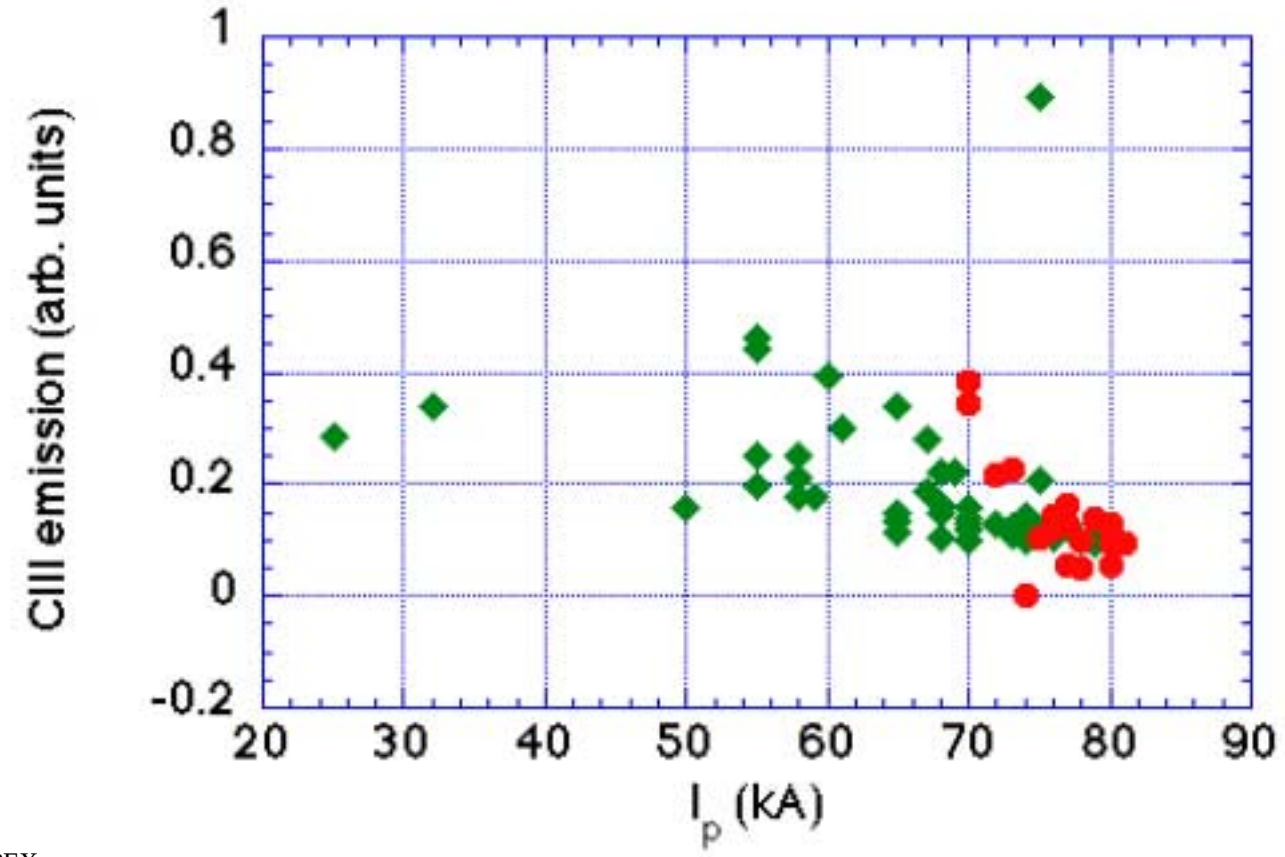
Edge density is not reduced local to the tray for the liquid lithium case

- Carbon III emission (sensitive to density) for hot and cold trays overlays.
  - Edge density similar for hot, cold trays.



R. Maingi

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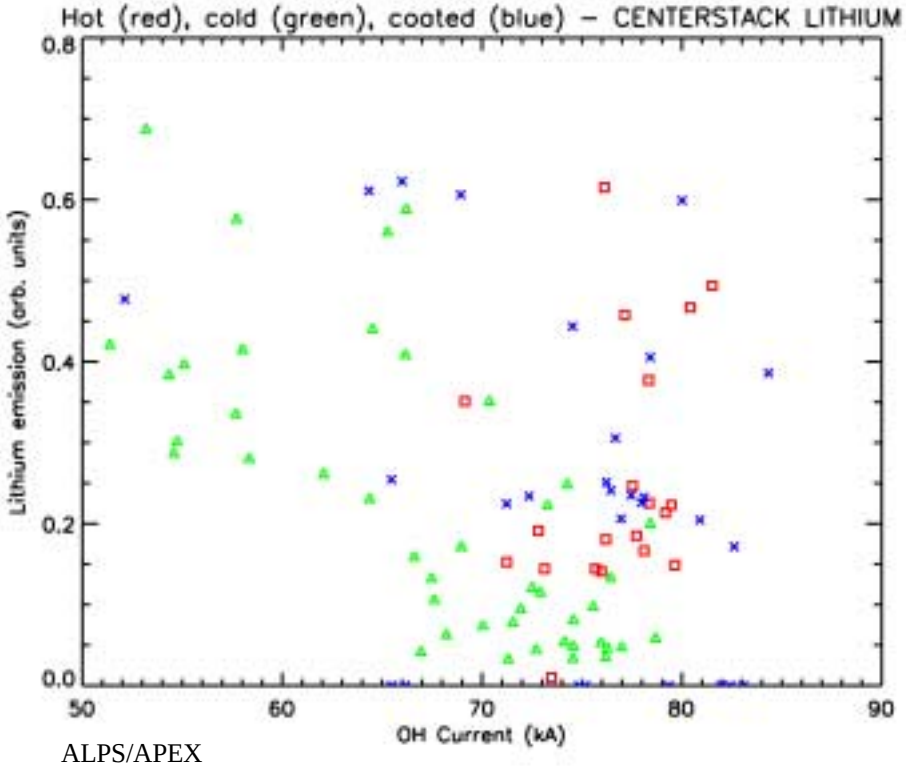
Operation with fully lithium coated walls

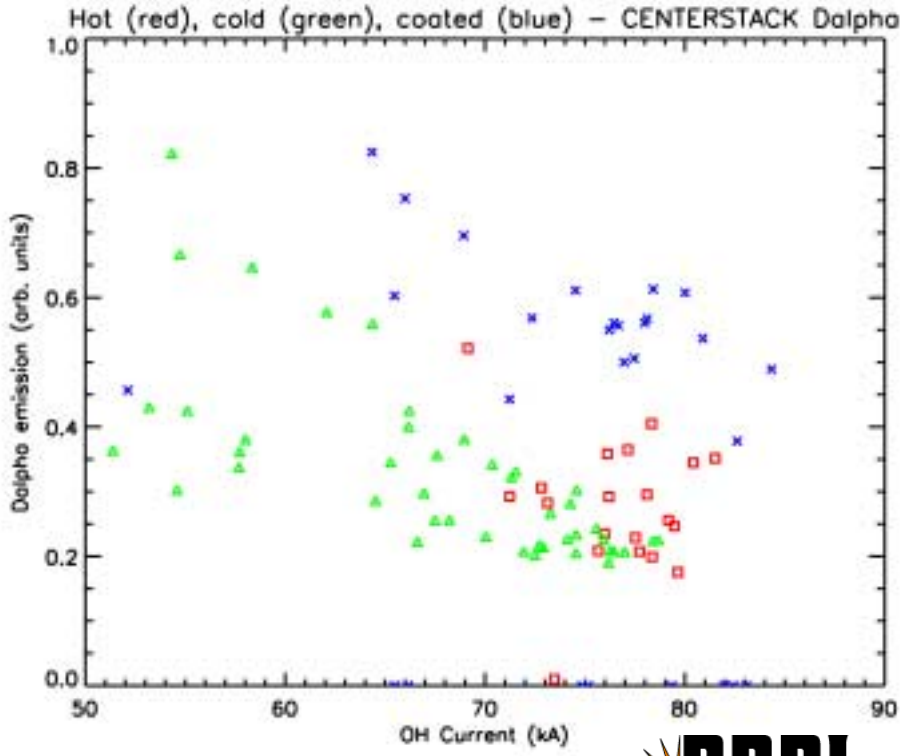
⇒Coating was mostly removed after an ethanol wash.
⇒Restored to pristine clarity after a water rinse.
Note that previous 8 months of operation produced no noticeable coating

- In early December 2001 a one-time coating "even" took place.
  - Occurred in the space of one hour during tray warm-up.
  - Never repeated; cause unknown.
  - Windows in line-of-sight from the tray were coated.
  - Gate valves would no longer completely seal.
- CDX-U operated afterward with interesting results.
  - Base pressure dropped by factor of 2-3.
  - Very difficult to fuel the discharge.
  - First slideaway discharges with significant fast electron energy in CDX-U history.
- Subsequently learned that repeated cycling of the gate valve (tens of operations) would restore the seal.
  - All gate-valve mounted viewports have now been replaced or cleaned.

Tokamak discharges were run shortly after the lithium coating "event"

- Very difficult to fuel the discharge
  - » Strong hydrogen pumping. Walls?
- Lithium emission from the centerstack is comparable to data with the tray hot
- Centerstack D_α data not indicative of a reduction in local recycling





Centerstack lithium, D_α emission

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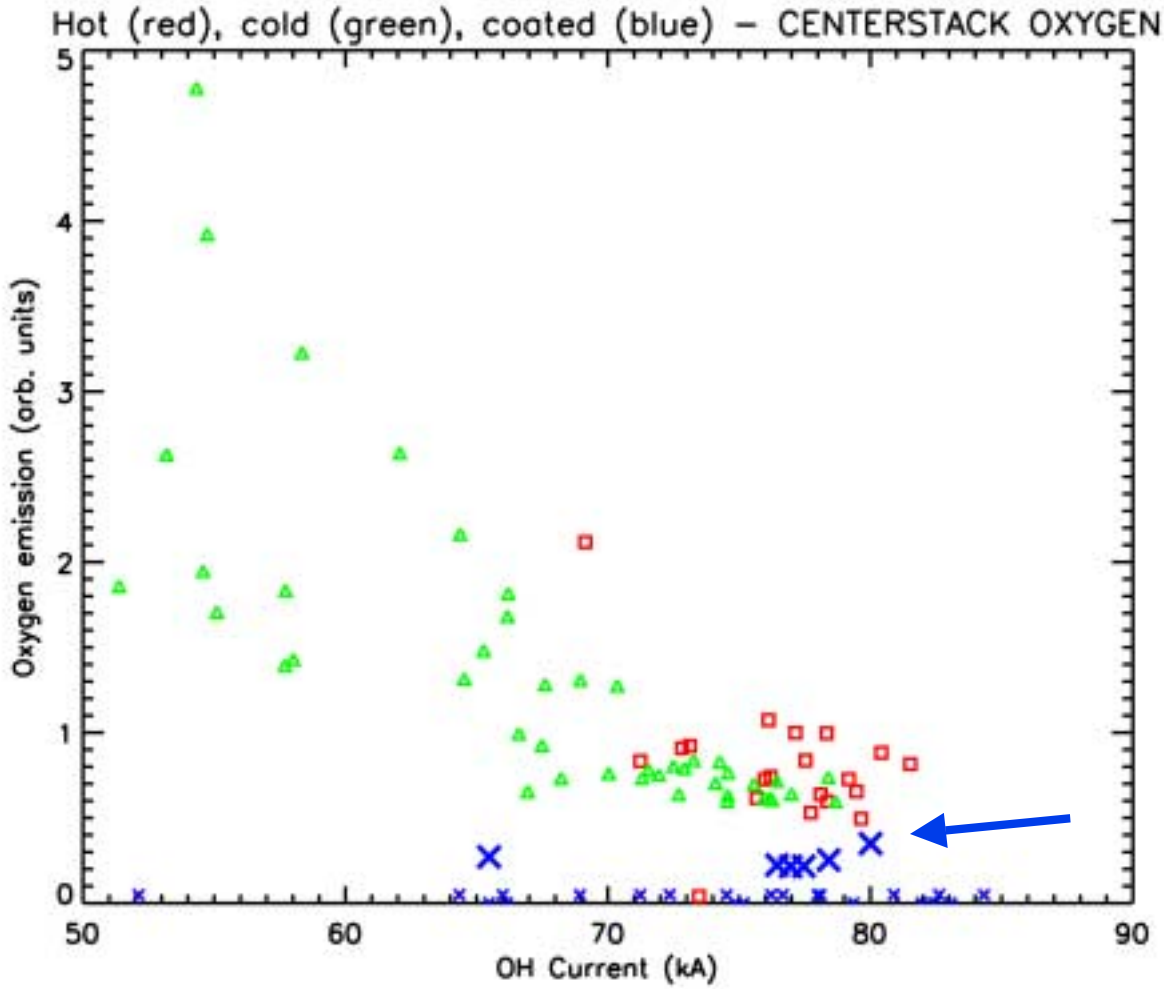
Performance enhancement with cold coated walls seems to be due to a reduction in oxygen



- Digitizer malfunction lost much of the oxygen filterscope data

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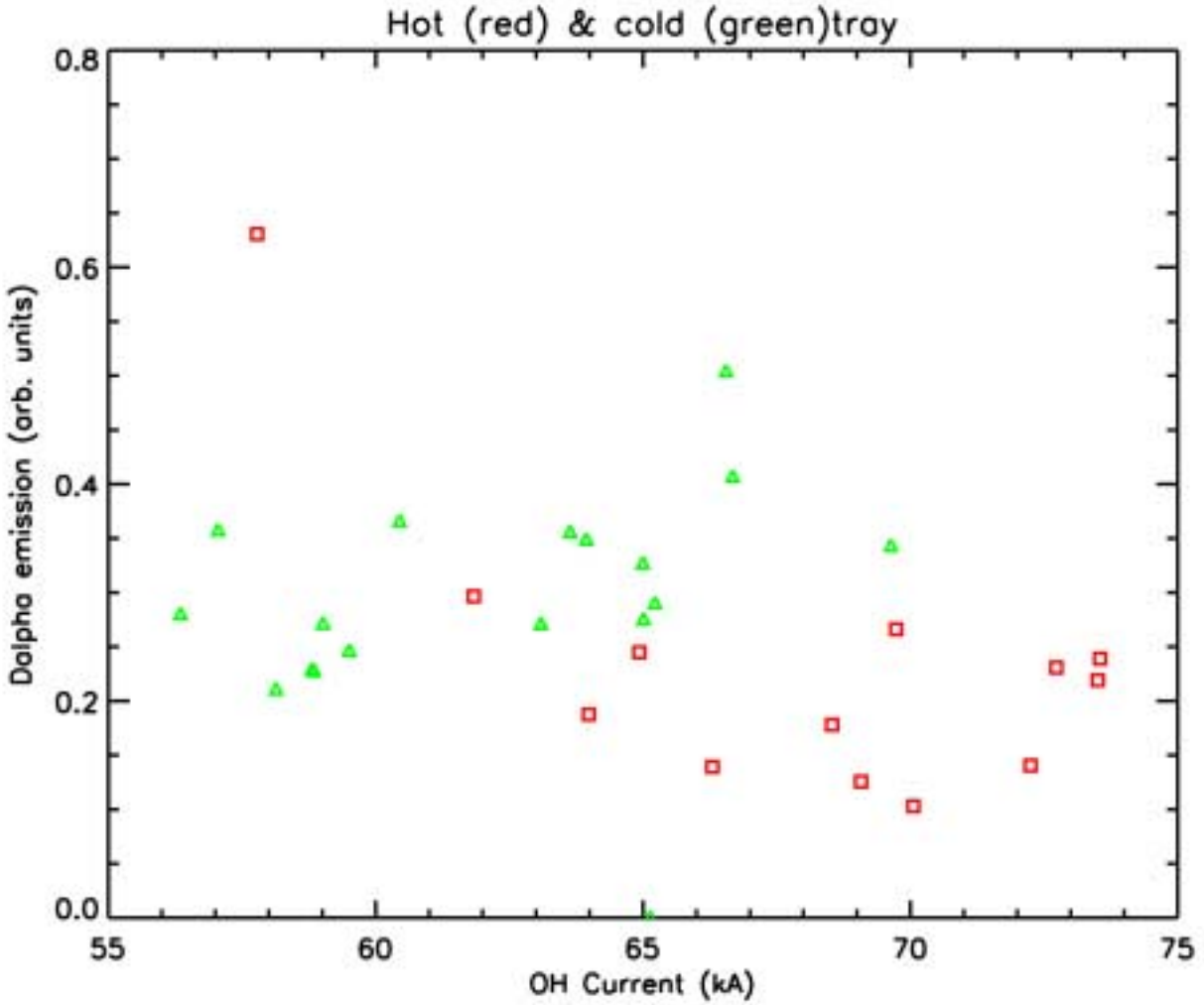
Full operation was eventually restored after the machine was coated (without a vent)

- Windows were cleaned after gate valve function was restored
- Both filterscopes now have lookdown views of the tray
- Additional spectroscopy installed
- New insertable low field side “stick” puffer installed
  - Operation just commencing
  - Intended to provide higher fueling efficiency
- New rf discharge cleaning electrodes should be completed next week
- Fast camera view partially recovered
  - Original tray view lost until a vent
- Thomson scattering windows still coated
  - However, laser not functional; requires maintenance

Reduction in tray D_α during tokamak operation with liquid lithium is still being observed

- Data taken 4/11/02 (hot) and 4/12/02 (cold)
  - Following overnight argon glow (original data followed 24 hour glow)



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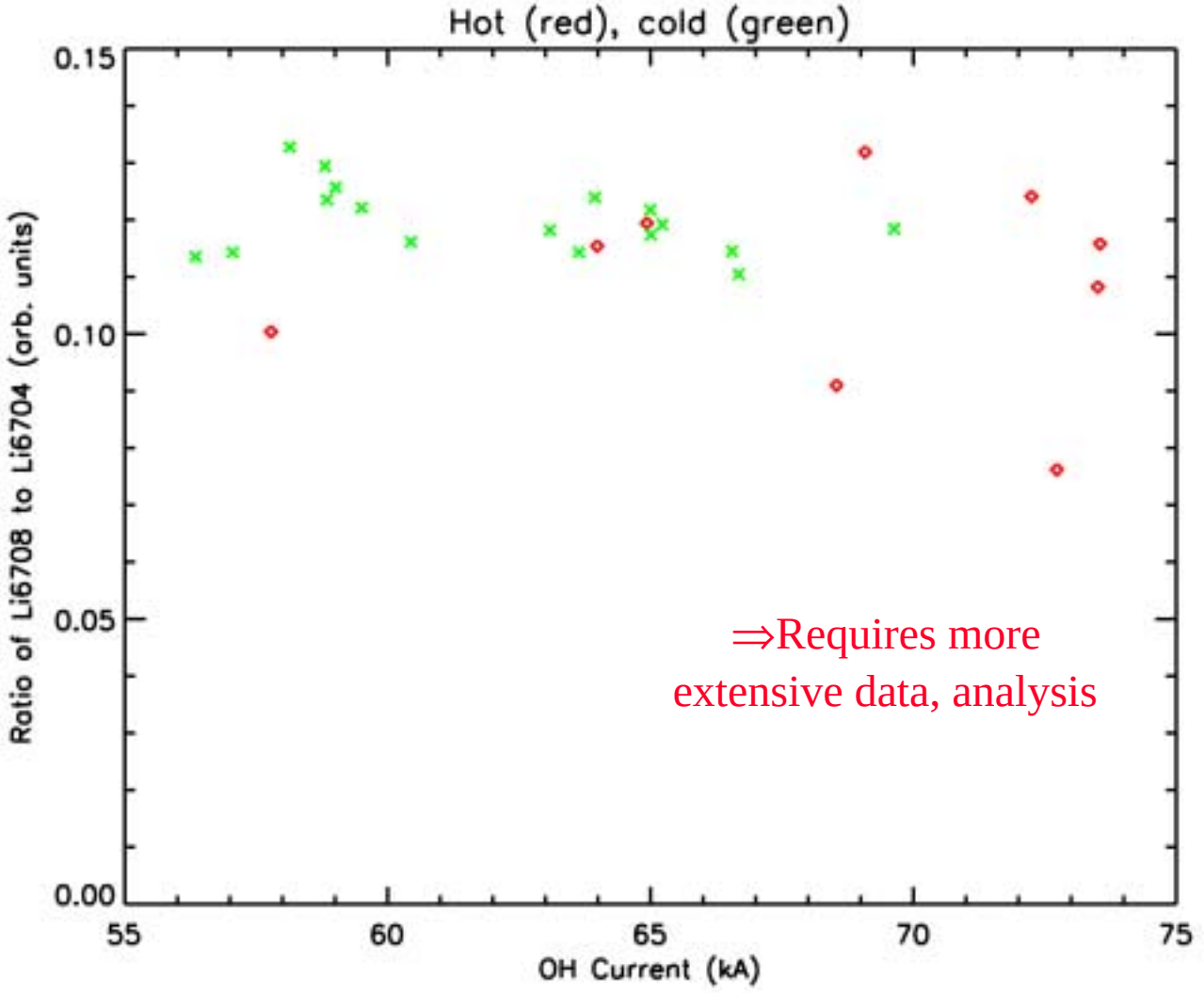
New spectroscopy indicates no evidence for an increase in edge T_e local to the tray

- Lithium 6708/6704 line ratio is sensitive to the electron temperature.



⇒Requires more extensive data, analysis

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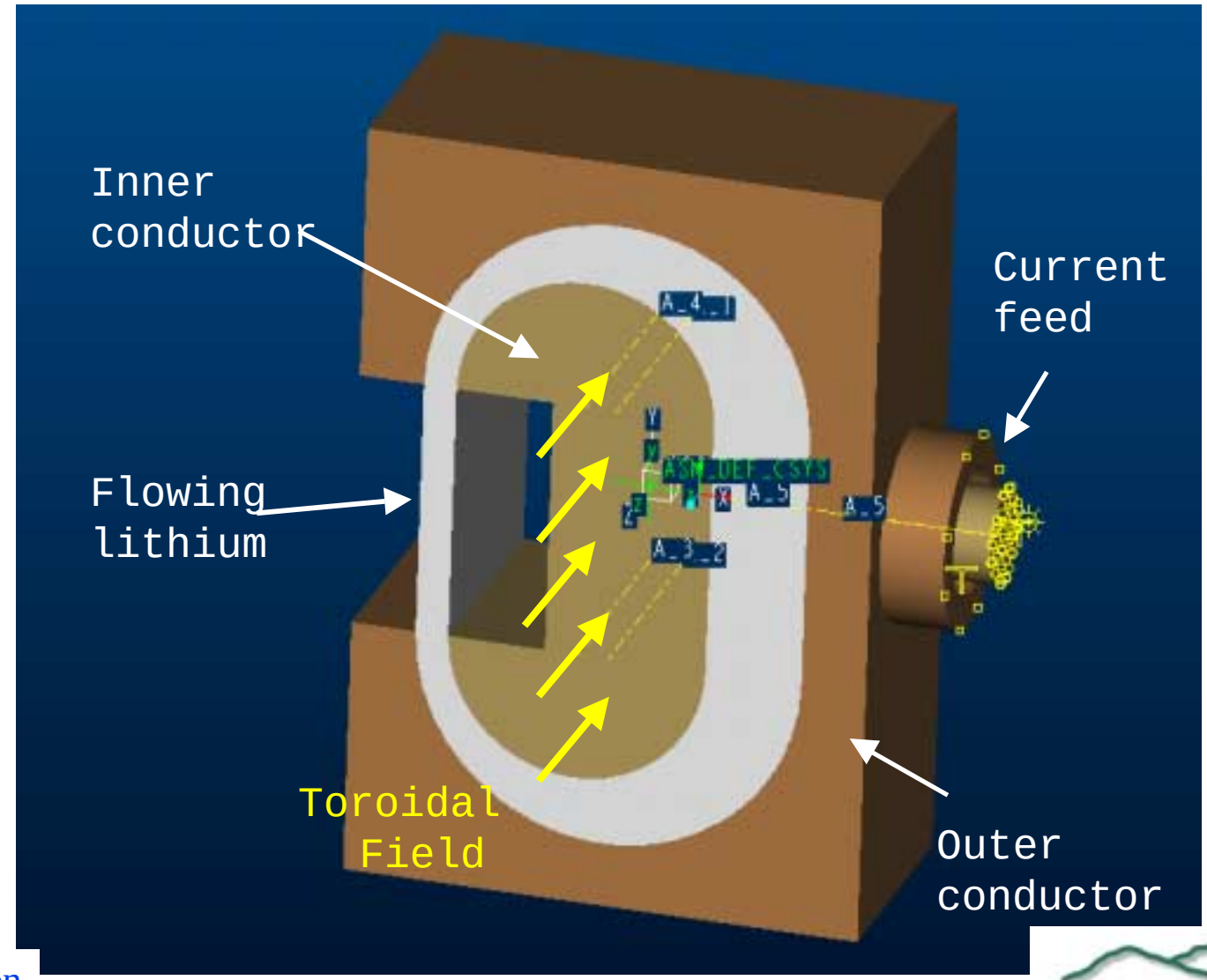
Next steps

- Tentative schedule:
  - Operate with the present tray until May (driven by PSI, IWIC-PIC)
    - » More hot tray experiments
    - » Also test new discharge cleaning, fueling techniques
- Replace tray beginning in June
  - New surface treatment, filling system
  - Testing underway at UCSD, PPPL
- Repeat experiments with better surface conditions
- In FY03, design and install a new, internally recirculating lithium limiter
  - Likely based on Brad Nelson's design for C-mod

Simplified Li divertor module for CMOD



Brad Nelson
ORNL

UT-BATTELLE

Summary

- Liquid lithium PFCs are shown to reduce recycling and impurities
  - Enhanced tokamak performance
  - Effect still observed in CDX-U nearly a year after original lithium loading
- Full lithium cold wall has a strong effect on impurities
  - Very efficient getter
  - Does not eliminate recycling, at least not in the 20-25 eV edge of CDX-U
- Improved fueling, discharge cleaning techniques beginning
- Tests of the new tray and filling technique are underway
- Preparing an ICC proposal to begin a lithium tokamak experiment (LTX) using the CDX-U facility